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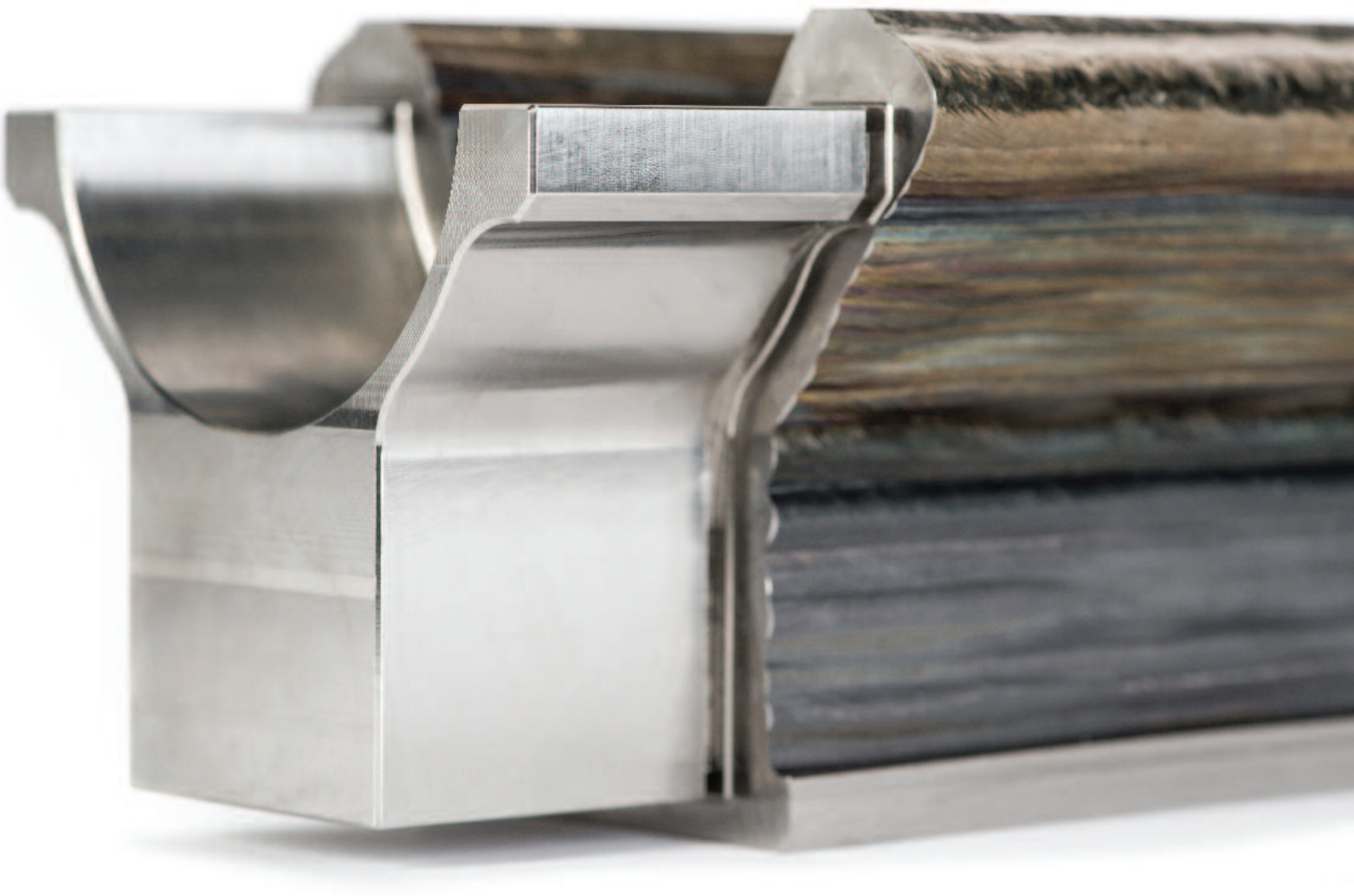
3-D PARTS FAST

Rapid Plasma Deposition may usher in a new industrial revolution



RAPID DEPLOYMENT

3-D printing moves from novelty to aerospace-grade solution able to revolutionize build rates, lead times

BY CORINNA PETRY

Tens of thousands of companies supply materials, parts, components and subassemblies to airframe builders. Lead times are universally known to be quite extended—over six years, even—which makes sense given the strict standards applied to every one of these parts to guarantee safety in flight. A jet engine alone may contain 25,000 disparate parts. The documentation for a Boeing 747 could not be lifted by a Boeing 747.

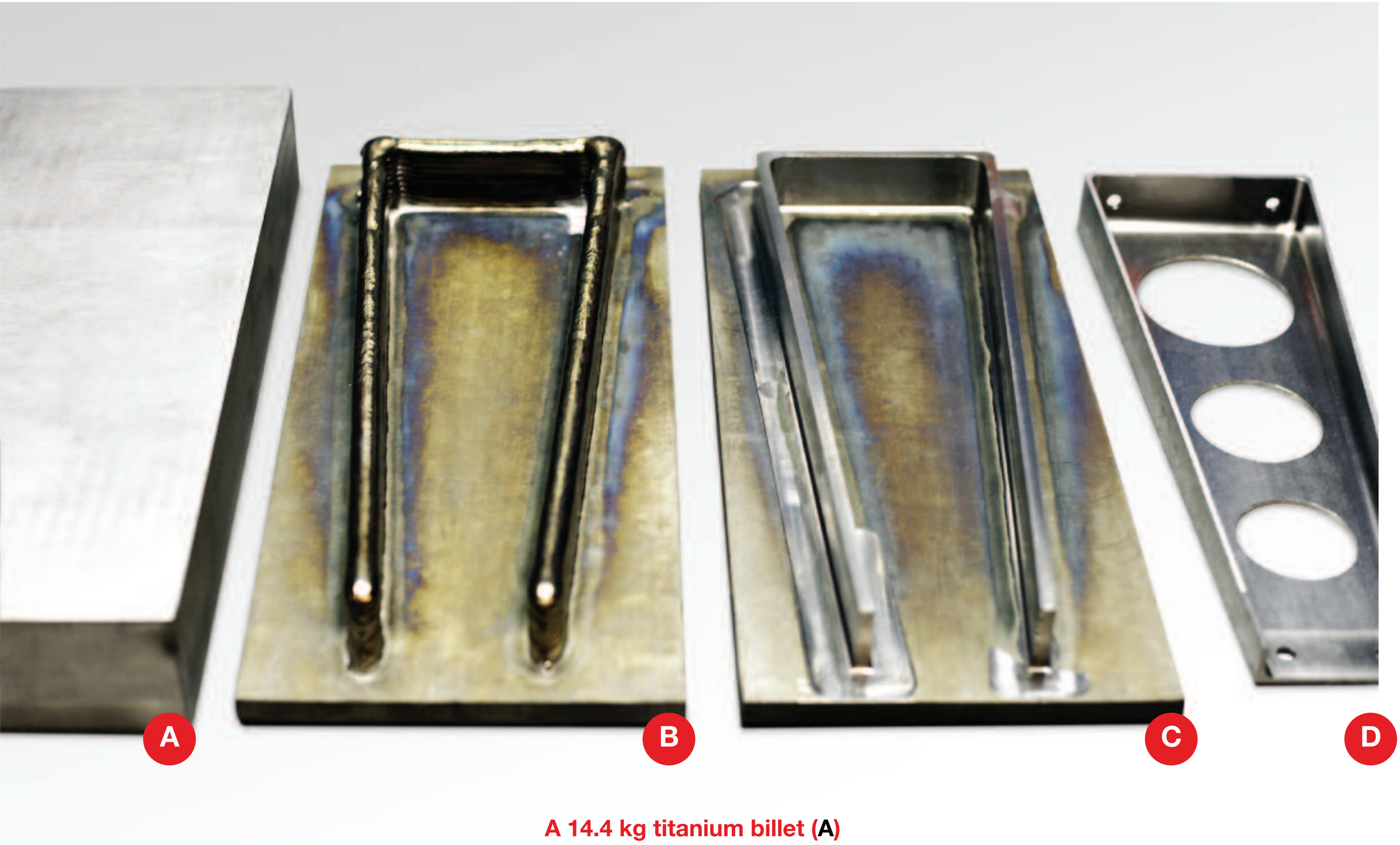
Enter additive manufacturing. One company, a titanium producer, has spent the past 10 years researching and developing a proprietary method for making aerospace parts that will cut lead times so drastically as to alter the supply chain forever. Don't blink, because this technology is going to an industrial scale this year.

Warren M. Boley Jr., president and CEO of Norsk Titanium, Oslo, Norway, insists he is not engaging in hyperbole when he calls the company's Rapid Plasma Deposition (RPD) a harbinger of the new industrial revolution.

R&D process

Norsk Titanium, launched in Norway in 2006, initially focused on using electrolysis to refine titanium, according to co-founder Petter Gjørvad, who was CEO for the first eight years. But despite teaming with Cambridge University, Norway Institute of Technology and Norsk Hydro, the resulting titanium production was found not to be economically viable.

That experience triggered a lightbulb moment for Gjørvad and co-founder Dr. Alf Bjørseth, who realized the cost of a tita-



A 14.4 kg titanium billet (A) machines to just 0.4 kg for a simple bracket (D) using legacy techniques. But a near-net-shape RPD form (B) produced by Norsk is machined for ultrasonic testing (C) before being finish machined to the flyable component (D).

nium aircraft part is less based on the material price than on the many hours of machining required to finish it from a billet or forging blank. Which meant that lowering titanium production costs would not create more cost-effective finished aircraft parts. So they studied ways to create near-net-shape titanium parts and analyzed all additive manufacturing technologies, including powdered metal, laser sintering and electron beam manufacturing. They settled on plasma plus wire as the only path that could make structural components that would withstand the unforgiving aerospace qualification process.

Production rates

RPD's manufacturing rates "enable an aircraft part to be built in additive layers in an hour or two, whereas other technology takes ten times that long," Boley says. "As a technology system, RPD is targeted for industrialization and commercialization so you that could feed a customer's airplane line with parts every day. It is a very rapid method of production, compared to powder technology, which is much slower," he claims.

Boley has an analogy for how entire steps are removed from the process between raw material and semifinished parts. "This is like taking a teapot of boiling water, pouring the water into a freezer, and instantly creating an ice cube without an ice cube tray. There is no mold. You are depositing titanium without a mold, a die or pattern."

Such a process requires significant process control, he notes, so Norsk Titanium developed an enhanced closed-loop control technology to perform RPD part manufacturing.

"This is a wire-fed argon plasma technology. The wire is fed at room temperature. The plasma arc raises the temperature of the wire by thousands of degrees and melts the titanium into liquid, then prints the liquid and that solidifies instantly," Boley explains.

Norsk Titanium is now on the fourth generation of RPD equipment, which looks like an everyday CNC machining center, but a plasma arc replaces the spindle. "The machine still has CNC controls and motion, and instead of having a cutting tool moving in five axes, a printer head moves relative to the titanium substrate," says Boley. With a footprint of roughly 25 square feet, the machine is also enclosed to keep the process clean and to keep workers safe.


Norsk Titanium's fourth generation RPD machine (background) produces qualification parts for a commercial airframe builder, with full production shipments to begin during the second half of 2016.

Weight reduction

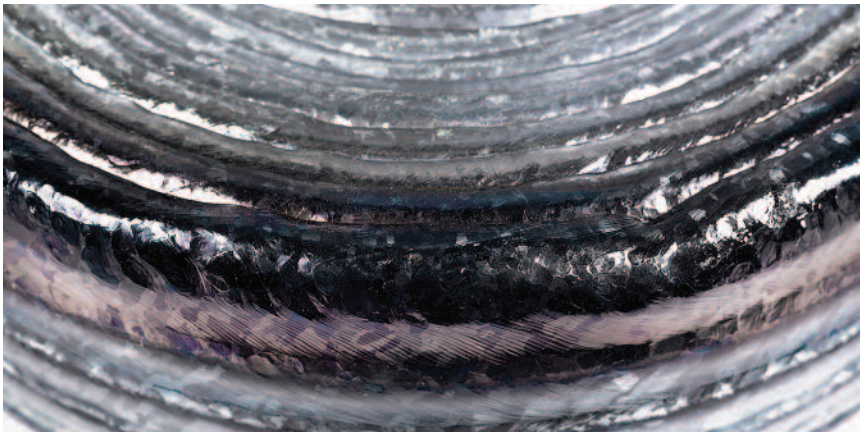
Instead of a 200-pound block of titanium that creates 20-pound aircraft part, "our part is 25 to 30 pounds to produce that 20-pound part," says Boley. It must still be machined but "you reduce time and waste, and so the cost savings is significant. 3-D printed titanium has an enviable buy-to-fly ratio. This enables the specification of titanium more often, and it becomes more affordable and available."

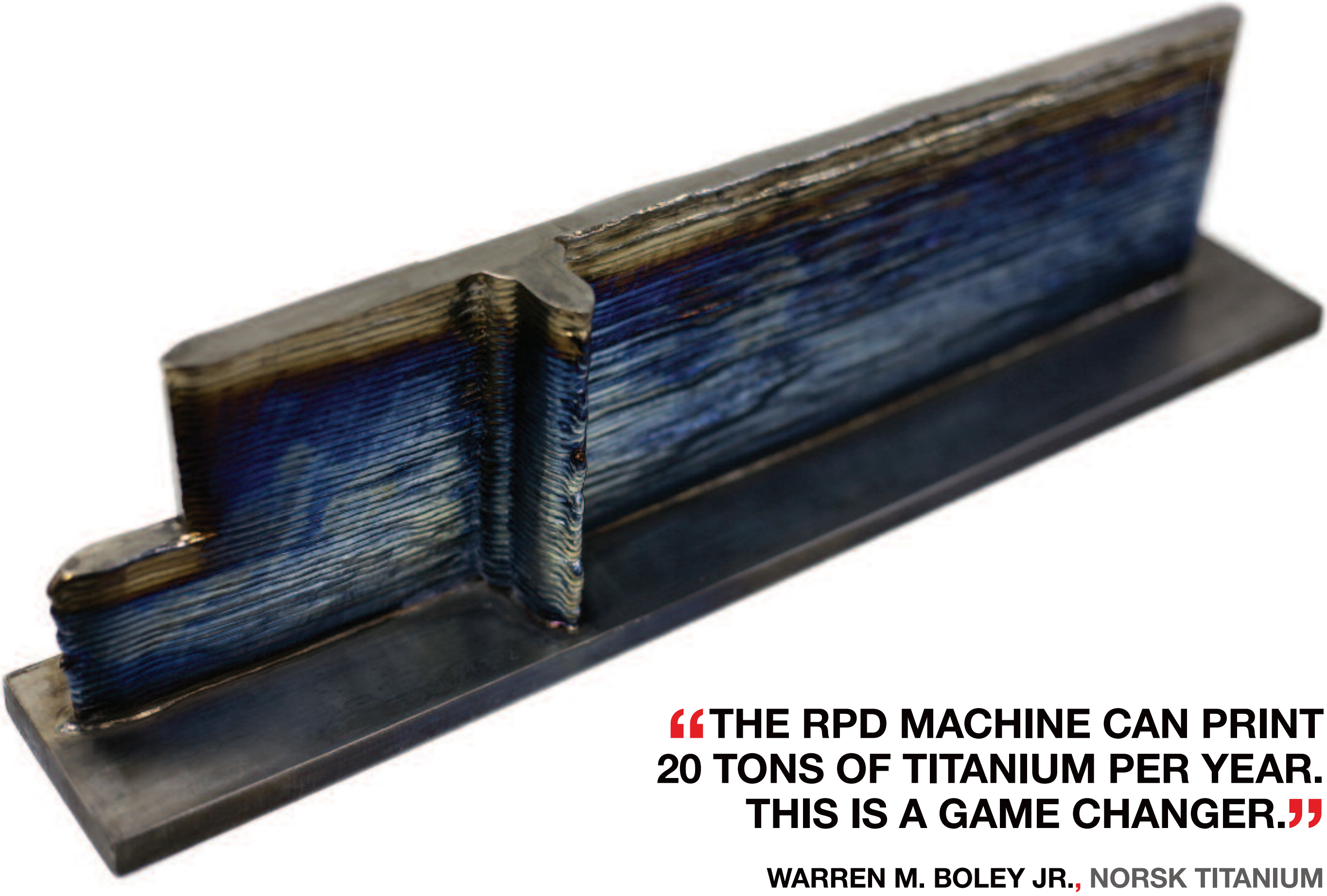
There is a green aspect of this technology associated with the reduction of energy consumption, he continues. In addition, "you are not using cutting fluids, you're not producing chips, you're not producing hazardous waste."

Apart from the wire feed, all the RPD line needs is a customer's CAD file. "You push a button and hours later you can produce up to 6,000 different aircraft components for Boeing or Airbus, Embraer or Bombardier."

The RPD machine and control software is Norsk Titanium's intellectual property, including the closed-loop control system that takes molten titanium and makes a structure. "The wire is titanium 6-4 wire, comes in a big roll and is fed into machine on a mandrel," says Boley. The RPD machine "can print 20 tons of titanium per year. This is a game changer in terms of being able to produce aircraft-quality titanium parts, compared with forging and rolling mills" that did the job for the past six decades.

In some ways, he says, airplane manufacturing "hasn't much changed since the first Boeing 707 rolled out in 1958. But now we can make all parts on one machine. It's a different entry point. With this technology, the barrier to entry is lower. You can have 50 to 100 machines in a factory and produce 2,000 tons of titanium a year. This is something that's not ever been done before in the industrial age."


Titanium RPD forms, upon close inspection, reveal a homogenous microstructure across layered deposited material.



> “THE RPD MACHINE CAN PRINT 20 TONS OF TITANIUM PER YEAR. THIS IS A GAME CHANGER.”
>
> **WARREN M. BOLEY JR., NORSK TITANIUM**

Lead times

The production of a 200-pound block of titanium, and the machining to get to a 20-pound airplane part, typically “requires a lead time of 55 to 75 weeks. And Norsk can print that in an hour or two,” says Boley. That kind of process provides a very different template for a customer’s cash flow and working capital management.

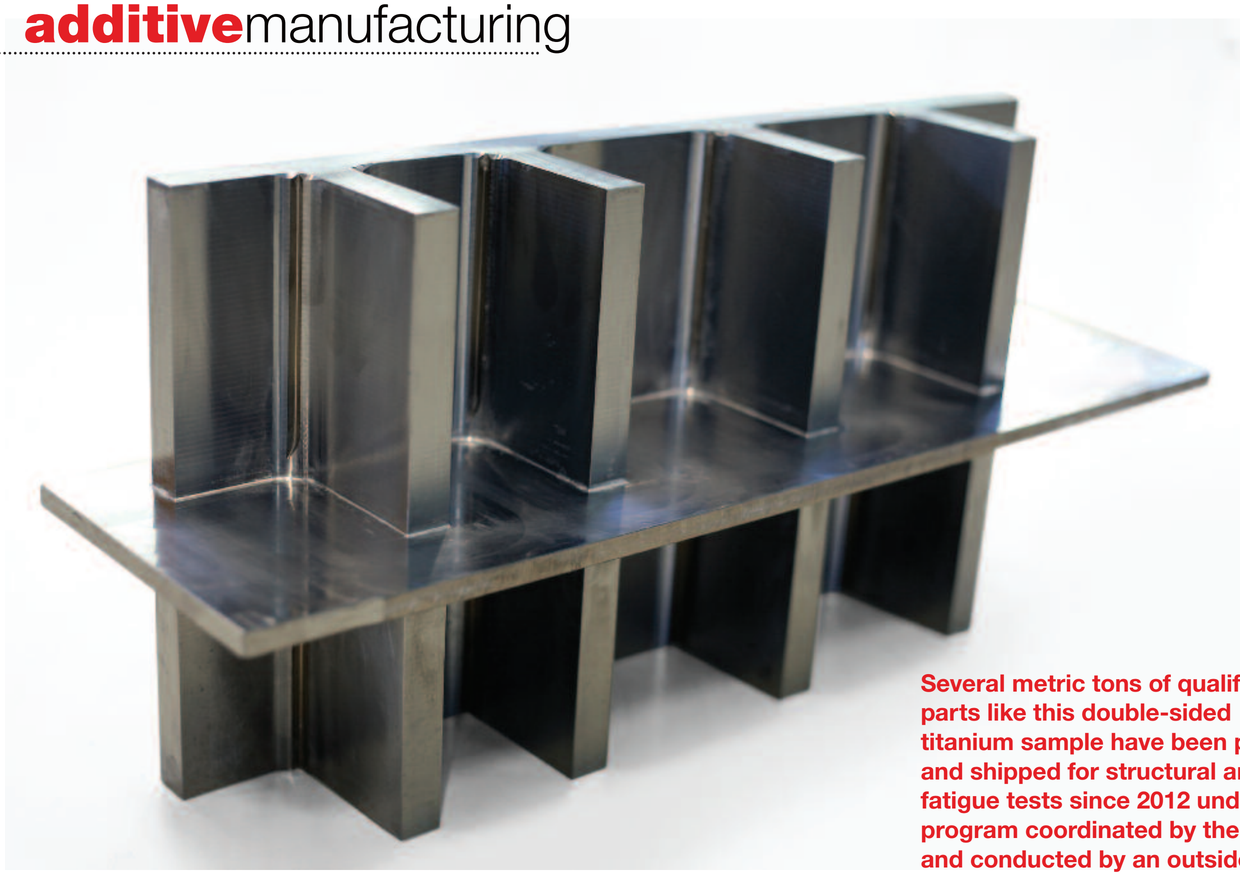
“If Boeing wanted to make 12 to 14 Dreamliners a month, we can feed its supply chain with a responsive process that doesn’t take years to set up; we can make a part in a day and deliver it the next day or next week. This saves inventory, and cash flow is orders-of-magnitude different. The inventory savings, the working capital, are revolutionary.”

In a three-stage process, near-net-shape RPD forms are machined for aerospace quality inspection and then finished for assembly.

Running a big batch of titanium at a rolling mill “is like an Apollo moonshot,” in terms of the planning needed, Boley says. With RPD, “a manufacturer like Boeing can now order a single part. The RPD machine doesn’t care what it produced yesterday or last week. It can build part A this hour, part B next hour and part C in the third hour. You get to one-piece flow, the ultimate lean expression.”

Value proposition

According to Boley, the potential savings



Several metric tons of qualification parts like this double-sided titanium sample have been printed and shipped for structural and fatigue tests since 2012 under a program coordinated by the FAA and conducted by an outside lab.

in cost per airplane model by using RPD could rise to "hundreds of millions of dollars a year."

Since late autumn, the company has demonstrated the technology to investors and aerospace customers practically around the clock. Norsk Titanium successfully completed 1,300 commercial aviation qualification tests to prove the metallurgical and structural integrity of the material, according to Boley. "We are working with the world's top aircraft OEM customers to get approval for all of their certifications." All the documentation for OEM standards submissions and government approvals—by the worldwide aviation authorities—are expected to come through during first quarter 2016.

Norsk is seeing at least one team of aerospace manufacturing engineering teams per week. "OEMs are very engaged. They want this in production in 2016," says Boley. In terms of raising money, "There is significant investor interest. We concluded one investor round and exceeded our [fundraising] expectations twofold. Every investor who sees the process invests."

In addition, the company is expecting major financial backing from an Eastern state. Hundreds of millions of dollars have already been committed by the state (and Norsk itself) toward building the world's first industrial-scale RPD production site. Boley declines to identify the state until the governor announces the deal. "All indications are that we are on track to commercialize in 2016."

Making history

Additive manufacturing, says Boley, is "part of the next industrial revolution. In 200 years it will be studied like the inventions of Samuel Slater [cotton mill] and John Sutter [sawmill]."

Chet Fuller, senior vice president and chief commercial officer, says that when Norsk tells an aircraft engineer that it "can take a part that once was created from 25 pounds of titanium and today make it with 4 or 5 pounds, it is compelling."

It may be an even stronger sell with new part specifications. "If you are making a brand-new airplane, and someone changes a specification in the wing, you have to get new titanium part made, and that now takes forever," Fuller says. "We don't need all that. We will have first-ever production that will go from wire to finished part in a compact production line of no more than 150 linear feet. This is not styrofoam or plastic; it's really hard material. We can make it cheaper, of course. That by itself would be enough, but [consider] the lead time associated with that, and the elimination of inventory carrying costs. If you cut 50 weeks out of working capital, that's enormous. That is an economic engine like nobody's ever seen."

Material competition

Even applied outside aerospace parts, Boley believes RPD-produced titanium will provide designers with "an alternative to aluminum as the cost of titanium comes down" and less weight is required for same structural application. "We are looking at life cycle costs of more affordable titanium versus heavier aluminum.

"That tradeoff will be significant," he continues. "You can fly farther and carry more gas, more passengers, more cargo. As 787s and A350s are now primarily composite, more will follow this trend, which requires the use of titanium components in combination with composites rather than aluminum, due to its significantly lower corrosion and compatible thermal expansion properties. That means lower maintenance costs for the airline. It all just becomes a win-win-win." ■

Norsk Titanium, New York, www.norsktitanium.no.

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